UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, WA 98101

December 1999

Summary of the Environmental Protection Agency's Columbia River Temperature Assessment Model

In accordance with Section 303 of the Clean Water Act, the states of Oregon and Washington have identified portions of the main stem of the Columbia River from the International Border (Columbia River Mile 745.0) to the mouth at Astoria, Oregon and the Snake River from Anatone, Washington (Snake River Mile 168.0) to its confluence with the Columbia River (Figure 1) as water quality limited. This designation arises from an analysis of data by the State of Washington's Department of Ecology and the State of Oregon's Department of Environmental Quality showing these waters do not meet water quality standards during all or part of the year. Under Section 303 (d) of the Clean Water Act, States are required to establish Total Maximum Daily Loads for pollutants at a level that implements the applicable standards for water temperature. The goal of Columbia River Temperature Assessment is to provide support for the priority-setting phase of the TMDL process by assessing the impacts of the principal sources of thermal energy. The central product of the temperature assessment was the development of a mathematical model that predicts temperature along the Columbia River from the Grand Coulee Dam to the Bonneville Dam and along the Snake River from its confluence with the Grande Ronde River (Snake River Mile 168) to its confluence with the Columbia.

The mathematical model predicts average daily temperatures, specific to locations along the lengths of the Rivers, but averaged across the width and depth of the Rivers. Key elements of the model include the ability to expand the model geographically, an algorithm that quantifies the uncertainty of the modeled results, and a twenty-one year database of temperature and climate data. The model is based on the energy budget method and uses an efficient numerical solution technique that simplifies the characterization of model uncertainty. The energy budget method accounts for the exchange of heat with the atmosphere and the input of advected thermal energy from major tributaries and points sources.

The temperature assessment includes a summary of a biological study on salmon and the impacts of temperatures on their various life-stages.

Study Objectives

The objective of this study was to determine, for a given sequence of hydrology and meteorological conditions, the relative impacts of the operation of dams and reservoirs on the thermal energy budget and ambient temperature regime of the main stem Columbia and Snake rivers compared to the impact of thermal input from surface and groundwater inflows. The specific objectives were:

- Estimate the magnitude and frequency with which daily-average water temperatures in the Columbia and Snake rivers will exceed the benchmark of 20°C under existing conditions of river management and a representative record of river hydrology and meteorology

- Estimate the magnitude and frequency with which daily-average water temperatures in the Columbia and Snake rivers will exceed the benchmark of 20°C for the unimpounded condition. That is, the condition in which there are no dams in place below Grand Coulee on the Columbia and on the Snake below Lewiston, Idaho.

- Estimate the magnitude and frequency with which daily-average water temperatures in the Columbia and Snake Rivers will exceed the benchmark of 20°C under existing conditions of river management and with major tributaries and point sources constrained to maintain temperatures less than 16°C.

- Characterize the uncertainty of these estimates for purposes of ultimately assessing the risks associated with potential management decisions in the Columbia and Snake rivers.

$

The benchmark of 20°C was chosen because it is at water temperatures greater than this that adult salmon are at risk. While the benchmark does represent certain aspects of the physiological requirements of salmonids, it is not viewed in the Report as a surrogate for water quality criteria or as part of an ecological risk analysis. The constraint of 16°C on maximum temperatures in the tributaries was based on the State of Washington's water temperature criterion for tributaries classified as Class A (excellent). However, the use of the constraint was not meant to imply that tributaries had attained this criterion or would do so in the future. Rather it was used to evaluate what the relative impact of the tributaries on the thermal regime of the main stems might be under very favorable conditions.

Model Scenarios

Three scenarios were defined for purposes of achieving the objectives of the assessment. The scenarios were designed to characterize the temperature regimes under the following conditions:

1. All hydroelectric facilities in the study area in place

2. The Columbia River unimpounded from Grand Coulee Dam to Bonneville and the Snake River unimpounded from Snake River Mile 168 to the confluence with the Columbia River.

3. All hydroelectric facilities in place and the water temperature of major tributaries constrained to be equal to or less than contribute water temperatures equal to or less than 16 °C.

A 21-year record of actual meteorological and hydrologic data for the Columbia and Snake rivers was used to represent the environmental variability of the system for all scenarios and management of water quantity in the system was assumed to remain the same for all scenarios.

Results

The average frequency of daily-averaged temperature excursions above 20 °C increased monotonically from 0.0 at Grand Coulee Dam on the Columbia River to 0.16 at Bonneville Dam for the scenario representing existing conditions (all hydroelectric facilities in place). The average magnitude of excursions increased from 0.0 °C to 1.6 °C between Grand Coulee Dam and Bonneville Dam. Corresponding values for average frequency of excursions for the unimpounded scenario were 0.0 to 0.03 from Grand Coulee Dam to Bonneville Dam. The average magnitude of temperature excursions at these sites for the unimpounded scenario increased from 0.0 °C and 0.3 °C. The average frequency and magnitude of excursions for the scenario in which tributary temperatures were constrained to be equal to or less than 16 °C were essentially the same as the scenario for existing conditions.

For the Snake River, the average frequency of daily-averaged temperature excursions above 20 °C increased from its initial value of 0.16 at Snake River Mile 168 to 0.19 at Ice Harbor Dam for the scenario representing existing conditions (all hydroelectric facilities in place). The average magnitude of excursions increased from 1.5 °C to 2.0 °C between Lewiston, Idaho and Ice Harbor Dam. The average frequency of excursions for the unimpounded scenario had an initial value of 0.16 at Snake River Mile 168, decreased slightly to 0.14 at Lower Granite Dame due to the influence of the Clearwater River, then increased to 0.15 at Ice Harbor Dam. The average magnitude of temperature excursions had an initial value of 1.5 °C at Snake River Mile 168, decreased slightly to 1.4 °C at Lower Granite Dam, then increased to 1.5 °C at Ice Harbor. The average frequency and magnitude of excursions for the scenario in which tributary temperatures were constrained to be equal to or less than 16 °C were reduced significantly at Lower Granite Dam, and only slightly Ice Harbor Dam as a result of the influence of the Clearwater River.

The impact of tributaries on the average frequency and magnitude of daily-averaged temperature excursions is related directly to their size relative to the main stem Columbia and Snake rivers. For the geographical scope included in the analysis, only the Clearwater River in relation to the Snake River and the Snake River in relation to the Columbia River had a significant impact on the thermal regime of the respective main stems. The Snake River is the most significant tributary to the Columbia River in terms of its impact on the temperature regime. The Snake River contributes to increases in both the frequency and magnitude of temperature excursions above 20 ºC for scenarios with dams in place as well as for scenarios for the unimpounded river. The Clearwater River provides cool water to the Snake and reduces both the frequency and magnitude of temperature excursions. Constraining the Clearwater River to water temperatures of 16 ºC or less results in significant cooling of the Snake River.

.

Conclusions

The following conclusions were drawn from the results:

- Structural changes in Columbia River downstream from Grand Coulee Dam and in the Snake River from its confluence with the Grande Ronde River to its confluence with the Columbia River near Pasco, Washington cause an increase in mean frequency and magnitude of water temperature excursions above a daily-averaged water temperature of 20 ºC relative to the unimpounded river. The structural changes are a result of the construction and operation of hydroelectric facilities on the Columbia and Snake rivers in the study area. This conclusion is based on a comparison of the mean frequency and magnitude of temperature excursions for the system as presently configured and for the same system in the unimpounded condition. The unimpounded condition assumes there are no dams on the Columbia River below Grand Coulee and no dams on the Snake River below Lewiston, Idaho. The uncertainty in these estimates is approximately of the order of the estimated differences in the results. Improving both the systems and measurements models could reduce uncertainty. This could include improving the quality of water temperature observations, increasing the spatial coverage of required meteorological data and by studying the seasonal variations in certain terms of the heat budget, particularly the evaporation rate. However, the conclusion that construction and operation of the hydroelectric facilities have a greater impact on the thermal regime of the Columbia and Snake Rivers than does thermal input from most major tributaries would not be changed by the reduction in uncertainty.

- The impact of most advected sources, including tributaries, groundwater and point sources, on the cross-sectional daily-average water temperature of the main stem Columbia and Snake rivers in the study area is limited by their relatively small contribution of advected thermal energy. The exceptions to this are the impacts of the Clearwater River on the cross-sectional daily-average water temperature of the Snake River and that of the Snake River on the cross-sectional daily-average water temperature of the Columbia River.

- The objective of the analysis was to assess the relative impact of dams and tributaries on the temperature regime of the Columbia River from Grand Coulee Dam to Bonneville Dam and Snake River from its confluence with the Grande Ronde River (River Mile 168) to its confluence with the Columbia River. The impact of upstream inputs was limited to the characterization of initial temperature conditions at Grand Coulee Dam on the Columbia River and River Mile 168 on the Snake River. However, upstream inputs have an important role in the temperature regime of both rivers. In the Columbia River, construction of Canadian impoundments and the operation of Grand Coulee Dam have an important role in the temperature of the Columbia River at Grand Coulee Dam. For the Snake River, initial conditions near Anatone, Washington are such that the mean frequency of temperature excursions is approximately 0.15 and the average magnitude of the excursions is approximately 1.5 ºC. This is due to structural changes to the natural river upstream from Anatone, Washington as well as to the time the river is exposed to high temperatures as it crosses the Snake River Plain. A larger geographical scope is needed to assess the basin-wide impacts of water management in both the Columbia and Snake rivers.